CLAIMS

WE CLAIM:

1. A method, comprising:

loading a microstructure into an etch chamber, wherein the microstructure comprises a sacrificial material and one or more structural materials;

providing a first discrete amount of spontaneous vapor phase etchant recipe during a first feeding cycle of a sequence of feeding cycles for removing the sacrificial material; and

providing a second discrete amount of the etchant recipe after the first feeding cycle and during a second feeding cycle that follows the first feeding cycle of the sequence of feeding cycles for removing the sacrificial materials.

2. The method of claim 1, further comprising:

filling the etch system with the first amount of the etchant.

3. The method of claim 1, further comprising:

filling the etch system with the second amount of the etchant.

4. The method of claim 1, wherein the first amount of etchant is fed during a first time slot of the first feeding cycle; and wherein the second amount of etchant is fed during a second time slot of the second feeding cycle.

5. The method of claim 2, wherein the time interval between the first and second time slot does not equal the time interval of the first feeding cycle.

6. The method of claim 1, wherein the time interval of the first feeding cycle does not equal the time interval of the second feeding cycle.

7. The method of claim 1, wherein the recipe comprises a spontaneous vapor phase etchant; and wherein the amount of the etchant in the first amount of the etchant recipe equals the amount of the etchant in the second amount of the etchant recipe.

8. The method of claim 1, wherein the time interval between the provisions of the first amount of the etchant recipe and the second amount of the recipe is predetermined.

9. The method of claim 1, further comprising: providing a third amount of the etchant recipe during a third feeding cycle of the sequence of feeding cycles from removing the sacrificial material; and wherein the time interval between the provisions of the first amount of the etchant and the second amount of the etchant does not equal the time interval between the provisions of the second amount of the etchant and the third amount of the etchant.

10. The method of claim 1, further comprising:

determining whether the amount of the sacrificial material inside the etch chamber is below a predetermined value.

11. The method of claim 10, wherein the predetermined value is 1% of the total amount of the sacrificial materials before etching.

12. The method of claim 10, further comprising:

dynamically detecting a concentration of an etching product; and

comparing the detected concentration with a predetermined value.

13. The method of claim 12, further comprising;

if a change of the detected concentration over a time unit is lower than a predetermined value, stopping the etching process.

14. The method of claim 12, further comprising:

if a change of the detected concentration over time is equal to or lower than the predetermined value, feeding the second amount of etchant into the etch chamber.

15. The method of claim 1, wherein the step of providing the first amount of the etchant further comprises:

(a) establishing a first pressure inside a first chamber, wherein the first pressure is equal to or lower than a pressure in a second chamber that contains a spontaneous vapor phase etchant;

(b) filling the first chamber with the etchant;

(c) filling the first chamber with a diluent gas such that the pressure inside the first chamber reaches a second pressure that is higher than the first pressure; and

(d) circulating the etchant and the diluent gas through the etch chamber.

16. The method of claim 15, further comprising:

establishing the second pressure inside the etch chamber by filling the etch chamber with the diluent gas before executing step (a).

17. The method of claim 16, wherein the step of (a) further comprises:

maintaining the second pressure inside the etch chamber.

18. The method of claim 16, wherein the step of (b) further comprises:

maintaining the second pressure inside the etch chamber

19. The method of claim 1, wherein the etchant recipe comprises a spontaneous vapor phase noble gas halide.

20. The method of claim 19, wherein the noble gas halide comprises xenon difluoride.

21. The method of claim 1, wherein the etchant recipe comprises a spontaneous vapor phase interhalogen.

22. The method of claim 19, wherein the interhalogen comprises bromine trichloride.

23. The method of claim 1, wherein the etchant recipe comprises is a spontaneous vapor phase HF.

24. The method of claim 1, wherein the etchant recipe comprises a diluent gas that is an inert gas.

25. The method of claim 24, wherein the inert gas is selected from N_2, He, Ar, Kr and Xe.

26. The method of claim 15, wherein the second chamber has a temperature equal to or higher than the temperature of the first chamber.

27. The method of claim 26, wherein the temperature of the second chamber is around 25° degrees.

28. The method of claim 15, wherein the second chamber has a cubical volume equal to or less than one twentieth of a cubical volume of the etch chamber.

29. The method of claim 15, wherein the steps (a) through (d) are sequentially executed such that a total time of the sequential execution is from 7.5 seconds to 15 seconds.

30. The method of claim 15, wherein the step (a) is executed for a time from 100 to 1500 milliseconds.

31. The method of claim 15, wherein the step (b) is executed for a time around 500 milliseconds.

32. The method of claim 15, wherein the step (c) is executed for a time from 1000 to 3000 milliseconds.

33. The method of claim 15, further comprising:

breakthrough etching the sample before establishing the second pressure inside the etch chamber.

34. The method of claim 15, further comprising:

coating the sample with a SAM material.

35. The method of claim 1, wherein the etchant has a pressure from 0.1 to 15 torr.

36. The method of claim 24, wherein the diluent gas has a pressure from 20 to 700 torr.

37. The method of claim 1, wherein the structural materials remain in the microstructure after the removal of the sacrificial material.

38. The method of claim 37, wherein the structural materials comprises:
a metal element, a metal alloy, a metal compound, a ceramic material or an anti-reflection film.

39. The method of claim 38, wherein the metal element is selected from Al, Ir, Ti, Ag, W, Ta and Mo.

40. The method of claim 38, wherein the metal alloy is selected from WTi_x, WMo_x, and WTa_x.

41. The method of claim 38, wherein the metal compound is selected from WAl_x, $AlTi_x$ and metal silicide.

42. The method of claim 41, wherein the metal silicide is selected from $AlSi_x$, WSi_x, $MoSi_x$, $TiSi_x$, $ZrSi_x$, $CrSi_x$, $TaSi_x$, $AlSi_xCu_y$ and TiW_xSi_y.

43. The method of claim 38, wherein the ceramic material is selected from silicon nitride, silicon carbide, polysilicon, titanium nitride, titanium oxide(s), titanium carbide, $CoSi_xN_y$, $TiSi_xN_y$, and $TaSi_xN_y$.

44. The method of claim 15, wherein the second amount of the etchant recipe is provided when the first amount of the etchant recipe is being circulated through the etch chamber.

45. A method for etching a sample in an etch chamber, the method comprising:

(a) establishing a first pressure inside a first chamber, wherein the first pressure is equal to or lower than a pressure in a second chamber that contains a spontaneous vapor phase etchant;

(b) filling the first chamber with the etchant;

(c) filling the first chamber with a diluent gas such that the pressure inside the first chamber reaches a second pressure that is higher than the first pressure; and

(d) circulating the etchant and the diluent gas through the etch chamber.

46. The method of claim 45, further comprising:

establishing the second pressure inside the etch chamber by filling the etch chamber with the diluent gas before executing step (a).

47. The method of claim 46, wherein the step of (a) further comprises:

maintaining the second pressure inside the etch chamber.

48. The method of claim 46, wherein the step of (b) further comprises:

maintaining the second pressure inside the etch chamber

49. The method of claim 45, further comprising: iterating an execution comprising the steps (a), (b), (c) and (d) a number of times.

50. The method of claim 45, wherein the etchant is a spontaneous vapor phase noble gas halide.

51. The method of claim 50, wherein the noble gas halide comprises xenon difluoride.

52. The method of claim 45, wherein the etchant is a spontaneous vapor phase interhalogen.

53. The method of claim 52, wherein the interhalogen comprises bromine trichloride.

54. The method of claim 45, wherein the etchant is a spontaneous vapor phase HF.

55. The method of claim 45, wherein the diluent gas is an inert gas.

56. The method of claim 55, wherein the inert gas is selected from N_2, He, Ar, Kr and Xe.

57. The method of claim 51, wherein the second chamber has a temperature equal to or higher than the temperature of the first chamber.

58. The method of claim 53, wherein the temperature of the second chamber is around 25° degrees.

59. The method of claim 45, wherein the second chamber has a cubical volume equal to or less than one twentieth of a cubical volume of the etch chamber.

60. The method of claim 45, wherein the steps (a) through (d) are sequentially executed such that a total time of the sequential execution is from 7.5 seconds to 15 seconds.

61. The method of claim 45, wherein the step (a) is executed for a time from 100 to 1500 milliseconds.

62. The method of claim 45, wherein the step (b) is executed for a time around 500 milliseconds.

63. The method of claim 45, wherein the step (c) is executed for a time from 1000 to 3000 milliseconds.

64. The method of claim 46, further comprising:

breakthrough etching the sample before establishing the second pressure inside the etch chamber.

65. The method of claim 49, further comprising:

detecting a status of a chemical species flowing out from the etch chamber;

performing a first iteration of the execution comprising the steps (a) through (d); and

performing a second iteration of the execution comprising the steps (a) through (d) after the first iteration depending upon the detected status of the chemical species.

66. The method of claim 65, wherein the status of the chemical species is the mole mass.

67. The method of claim 65, further comprising:

stopping etching the microstructure when the status of the chemical species reaches a predetermined value.

68. The method of claim 67, wherein the status of the chemical species is an etching rate.

69. The method of claim 67, wherein the predetermined value is 1% or less.

70. The method of claim 67, wherein the chemical species is selected from SiF, SiF_3 and SiF_4.

71. The method of claim 67, further comprising:

coating the sample with a SAM material.

72. A method, comprising:

loading a microstructure into an etch chamber, wherein the microstructure comprises a sacrificial material and one or more structural materials;

circulating a first amount of spontaneous vapor phase etchant recipe via a first loop that passes through the etch chamber for removing the sacrificial material; and

circulating a second amount of the etchant recipe via a second loop that passes through the etch chamber and a first chamber other than the etch chamber for removing the sacrificial material, wherein the first chamber is not part of the first loop.

73. The method of claim 72, wherein the step of circulating the first amount of etchant via the first loop is performed for a time period determined by a chemical reaction rate of the etchant with a component of the sample.

74. The method of claim 73, wherein the time period is from 500 to 3500 milliseconds.

75. The method of claim 74, wherein the time period is from 1000 to 3000 milliseconds.

76. The method of claim 73, further comprising:

detecting a status of a chemical species; and

stopping the etching process when the status of the chemical species reaches a predetermined value.

77. The method of claim 73, wherein the chemical species is selected from SiF, SiF_3 and SiF_4; and wherein the status is molar mass.

78. The method of claim 72, wherein the step of circulating the second amount of etchant recipe via the second loop is performed when the first amount of the etchant recipe reaches a critical value.

79. The method of claim 78, wherein the critical value of the etchant is dynamically determined based on a chemical reaction between the etchant and a component of the sample.

80. The method of claim 72, wherein the etchant recipe comprises a spontaneous vapor phase noble gas halide.

81. The method of claim 80, wherein the noble gas halide is xenon difluoride.

82. The method of claim 72, wherein the etchant recipe comprises a spontaneous vapor phase interhalogen.

83. The method of claim 82, wherein the interhalogen comprises bromine trichloride.

84. The method of claim 72, wherein the etchant recipe comprises a spontaneous vapor phase HF.

85. The method of claim 72, wherein the etchant recipe comprises a diluent gas.

86. The method of claim 85, wherein the diluent gas is an inert gas.

87. The method of claim 86, wherein the inert gas is selected from N_2, He, Ar, Kr and Xe.

88. The method of claim 72, wherein the etchant recipe comprises a spontaneous vapor phase etchant; and wherein the amount of the etchant in the first amount of the etchant recipe equals the amount of the etchant in the second amount of the etchant recipe.

89. The method of claim 72, wherein the etchant recipe comprises a spontaneous vapor phase etchant; and wherein the amount of the etchant in the first amount of the etchant recipe does not equal the amount of the etchant in the second amount of the etchant recipe.

90. The method of claim 81, wherein the structural materials remain in the microstructure after the removal of the sacrificial material.

91. The method of claim 90, wherein the structural material comprises a metal element, a metal alloy, a metal compound, a ceramic material or an anti-reflection material.

92. An etching system for etching a microstructure, the system comprising:

an etchant source having a selected spontaneous vapor phase etchant;

a first chamber containing the microstructure;

a second chamber connected to the etchant source;

a first circulation loop that connects the first chamber but not the second chamber for enabling the circulation of the etchant through the microstructure in the etch chamber; and

a second circulation loop that connects the first and the second chamber for enabling the circulation of the etchant through the microstructure in the etch chamber and a provision of the etchant.

93. The system of claim 92, wherein the etchant is a spontaneous vapor phase noble gas halide.

94. The system of claim 93, wherein the noble gas halide is xenon difluoride.

95. The system of claim 92, wherein the gas etchant is a spontaneous vapor phase interhalogen.

96. The system of claim 95, wherein the interhalogen comprises bromine trichloride.

97. The system of claim 92, wherein the second chamber contains a mixture of the etchant and a diluent gas that is selected from N_2, He, Ar, Kr and Xe.